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Large-Signal Code TESLA: Improvements in the Implementation and in the Model

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Abstract: We describe the latest improvements made in the large-signal code TESLA, which include transformation of the code to a Fortran-90/95 version with dynamical memory allocation and extension of the model for more accurate treatment of slow and reflected particles.

Keywords: large-signal hybrid code; high-power klystron amplifiers; Fortran-90/95; slow and reflected particles;

Introduction

The large-signal hybrid code TESLA has been developed [1] as a tool for the simulation and design of high-power klystron amplifiers. The code has been tested for different klystron configurations [2], and it is used now as a design tool at NRL [3,4]. The main features of the code that make it attractive are its ability to accurately model self fields along with its short run time and moderate computer resource requirements. During the last year we have extended the model and improved the numerical implementation of the code. Specifically, we have modified the physical model to allow for the proper treatment of slow or trapped electrons. The numerical implementation has been improved by going to a Fortran-90/95 format that allows for more efficient use of computer memory. Finally, the code is in the process of parallelization specifically for multi-beam configurations.

Results

The previous implementation of the code TESLA (up to its latest officially released version 2.4) was based on the Fortran-77 language standard, which uses a static memory model that required declaration in advance of all the sizes for the numerical arrays. This resulted in inefficient memory use and limited the possibility of extension of the model. Also, the existing unstructured Fortran code was hard to support and to extend as well. To overcome these limitations the code was first re-structured and, then re-written by use of the Fortran-90/95 language standard [5]. The introduction of dynamical memory allocation have made the memory usage completely dependable on the

user's input parameters and reduced the memory usage dramatically (~ 9 times). Also additional optimization applied to the algorithm and its implementation reduced the run-time of TESLA almost by a factor of two. Advanced output diagnostics during execution were added, including estimates for the memory usage and for the time of the run.

The numerical efficiency of TESLA is based partly on the fact that it solves for the trajectories of electrons with axial distance the electron has traveled, rather than time, as the independent parameter. This approach is applicable only when the electron's axial position increases monotonically as it passes through the device, and it fails if the electron is significantly slowed down or reflected. To overcome this limitation, a more accurate treatment has been implemented in TESLA [6]. Once a particle's velocity falls below a chosen threshold (v_{z-th}), the particle is considered to be a "special" particle and its trajectory is integrated in time (rather than in axial coordinates). The time integration continues until the particle will be re-accelerated above the threshold and then it will be returned to the pool of "normal" particles. Particles that remain below the threshold are integrated in time until they leave the device.

To test newly implemented approach, the klystron configuration was used similar to the NRL 4-cavity MBK design [3]. The value of R/Q for the output cavity $(R/Q)_{out}$ was varied from its working value $(R/Q)_w \sim 37.5$ Ohm to create artificially more "special" particles in the device. Figure 1 displays the dependence of output power from the value of $(R/Q)_{out}$, predicted by the new, accurate treatment (curve 1): the $(R/Q)_{out}$ increase ($\gg (R/Q)_w$) results in the output power "saturation" and then its subsequent decrease. This result is in a big contrast with the predictions of the previously used in TESLA approximate approach (curve 2). An example of phase space for a test case with the $(R/Q)_{out} = 52.5$ Ohm $= 1.4(R/Q)_w$ is presented on Figure 2: the particles with velocity below the threshold (including reflected particles) are shown there as gray dots.

An essential difference of the new approach is that its results are insensitive to the level of the threshold parameter v_{z-th}/v_{z-init} , which is an input parameter in the code (Figure 3).

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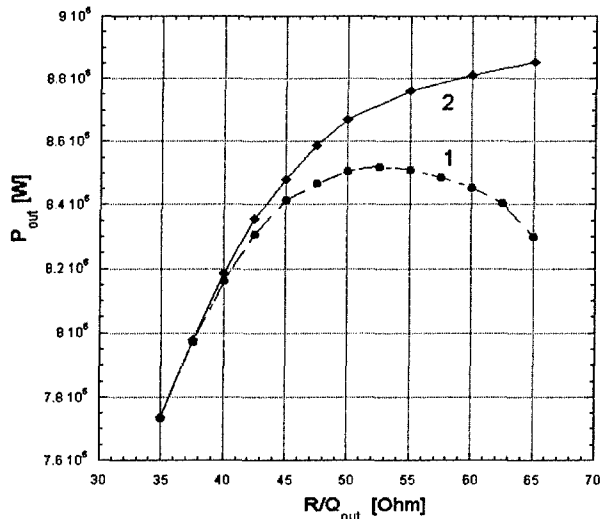


Figure 1. Output power versus the value of $(R/Q)_{out}$, calculated by use of the new, more accurate treatment (curve 1) and with the previous, approximate approach (2).

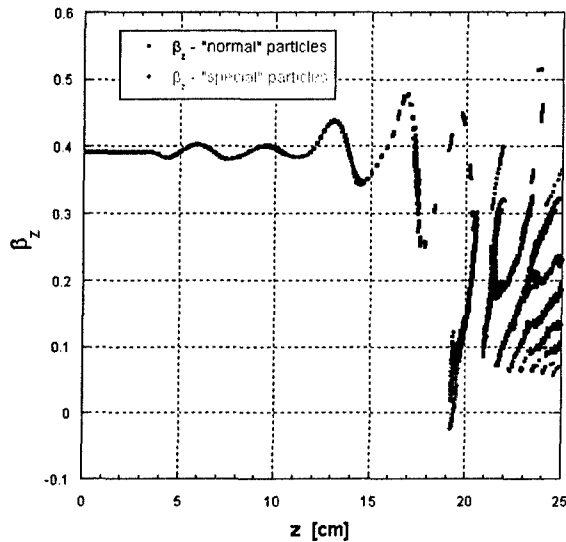


Figure 2. Phase space plot with two distinct sets of the "normal" (black circles) and "special" (grey circles) particles at the vicinity of the output cavity of the test 4-cavity klystron configuration with increased R/Q .

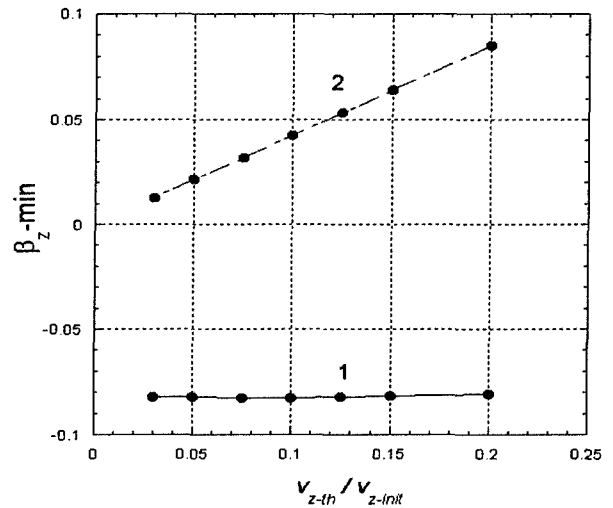


Figure 3. Predictions for the particle's minimum velocity depending on the threshold parameter, obtained by help the new treatment (curve 1) and the previous, approximate approach (2).

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